January 1982

EPA 600/3-82-006

DEPENDENCE OF NEPHELOMETER SCATTERING COEFFICIENTS ON RELATIVE HUMIDITY

Fronts, Nocturnal Disturbance, and Wood Smoke

ENVIRONMENTAL SCIENCES RESEARCH LABORATORY
OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
RESEARCH TRIANGLE PARK, NORTH CAROLINA 27711

DEPENDENCE OF NEPHELOMETER SCATTERING COEFFICIENTS ON RELATIVE HUMIDITY
Fronts, Nocturnal Disturbance, and Wood Smoke

by

George W. Griffing
Meteorology and Assessment Division
Environmental Sciences Research Laboratory
Research Triangle Park, North Carolina 27711

ENVIRONMENTAL SCIENCES RESEARCH LABORATORY
OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
RESEARCH TRIANGLE PARK, NORTH CAROLINA 27711

DISCLAIMER

AUTHOR AFFILIATION

The author is on assignment with the U.S. Environmental Protection Agency from the National Oceanic and Atmospheric Administration, U.S. Department of Commerce.

ABSTRACT

The dependence of the nephelometer scattering coefficient of atmospheric air on the relative humidity at the RTP is discussed for four different meteorological examples. These examples feature (1) the passage of a low pressure system with thunderstorms, (2) the passage of a cold, dry front, (3) a nocturnal weather disturbance due to an unknown source, and (4) wood smoke aerosols from burning tree piles. Nephelometer scattering coefficient data were obtained by the use of two nephelometers. One nephelometer was operated at the ambient outside relative humidity and the other nephelometer at a different relative humidity. Using this operational mode of data acquisition, qualitative temporal information can be deduced on the variations of aerosol size and number density as the various meteorological parameters vary. In addition to discussions on the variations of these aerosol physiochemical parameters, the temporal trend of the visibility is discussed for each example.

CONTENTS

FIGURES

TABLE

ACKNOWLEDGEMENT

The technical assistance of Mr. Ralph Soller with the equipment for the observations is gratefully acknowledged.

SECTION 1

INTRODUCTION

The quantity measured by an integrating nephelometer[1], when atmospheric air is flowing through the nephelometer, will be called the scattering coefficient. For the nephelometer used in these studies, the scattering coefficient is a composite of contributions by the atmospheric aerosols and gases. In general, the scattering coefficient varies with time because of temporal changes in the optical properties of the aerosols. These optical properties are determined by the physiochemical parameters[2] characterizing the aerosols such as number density, size, chemical composition, and shape of the aerosols.

Reasons for temporal variations of the aerosol physiochemical parameters are easily conceived. For instance, the aerosol number density might vary because of emission variations by a source. The aerosol number density could also vary because precipitation has purged some of the aerosols. An increase of the relative humidity could result in aerosol growth[3,4]. The relative humidity could also produce changes in the shape and chemical composition of the aerosols. Clearly, many other reasons for temporal variations of the aerosol physiochemical parameters could be presented. As mentioned, it is conceivable that an increase (decrease) of the relative humidity could induce aerosol growth (shrinkage) which would lead to an increase (decrease) of the scattering coefficient. However, even if the scattering coefficient increased (decreased) when the relative humidity increased (decreased), it is also conceivable that the increase (decrease) of the scattering coefficient was due to an increase (decrease) of the aerosol number density since it is possible that the relative humidity variations were incidental to the cause for the increase (decrease) of the scattering coefficient. By operating two nephelometers simultaneously at two different relative humidities, it is clear that the ambiguity on the reason for variations of the scattering coefficient could, at least in part, be removed. This operational mode was used in our studies.

Insitu observations on the scattering coefficient and relative humidity have been taken simultaneously in a nearly continuous mode since December 1978. Some of the data on the dependence of the scattering coefficient on the relative humidity have been discussed[5]. Of particular interest was a phenomenon which was called an aerosol burst. The term--aerosol burst--was used to characterize the behavior of the scattering coefficient which increases relatively rapidly and subsequently decreases relatively rapidly during a 2- to 3-hour period. Most usually an aerosol burst occurs after sunup and is associated with an anticyclonic weather system. An aerosol burst is due to a composite of aerosol growth and shrinkage and an increase and decrease of the aerosol number density.

In Section 2, certain important aspects of the instrumentation for data procurement are discussed. The data for four rather diverse meteorological examples are analyzed and discussed in Section 3. For each example, the corresponding temporal visibilities are discussed in Section 4. In Section 5, the report is concluded with a few remarks concerning the significance of the research.

SECTION 2

DATA PROCUREMENT

A description of the instrumentation has been given[5]. However, to better understand the meaning of terms used in later discussions, it will be helpful to mention certain features of the instrumentation.

One nephelometer, referred to as the outside nephelometer, was located in a wooden shed on a platform about 6 m above ground level. To maintain ambient temperatures in the shed, a large fan was used to ventilate the shed. The temperature of air flowing through the nephelometer was at ambient. The scattering coefficient data obtained with the outside nephelometer is called the outside scattering coefficient and the corresponding relative humidity is called the outside relative humidity.

Another nephelometer, referred to as the inside nephelometer, was located in an air-conditioned room. Before the outside air enters the scattering chamber of the inside nephelometer, the temperature of the air was determined to be approximately equal to the ambient room temperature. The scattering coefficient data obtained with the inside nephelometer is called the inside scattering coefficient and the corresponding relative humidity is called the inside relative humidity. The reader is cautioned that the terms, inside scattering coefficient and relative humidity, are not for the air in the room. Inlet orifices for outside air to the inside and outside nephelometers were about 6 m above the ground and separated by about 50 m horizontally.

There were other data which were useful in analyzing the nephelometer data. These data were (1) solar radiation data, (2) temperature gradient data, (3) wind speed and direction data, and (4) acoustic sounder data. The solar radiation sensors were located on the platform near the nephelometer and about 6 m above ground level. The temperature gradient data were taken with temperature sensors located 1 and 6 m above ground level. The wind sensors were located at about 6 m above ground level. The acoustic sounder was located at ground level in the immediate vicinity of the other instruments.

In addition to these data, the hourly weather observations at the Raleigh-Durham weather station (RDU) were used in the analysis of the nephelometer data. RDU is located approximately 6 km to the east of the Research Triangle Park (RTP) observational site and both are located in a non-urban environment. Generally, both sites would be expected to be affected similarily with respect to ambient air pollution. However, on rare occasions, the RTP has been affected by emissions from sources such as burning tree piles while the RDU has not been affected by those emissions. Such an example is discussed in Section 3(d).

SECTION 3

SCATTERING COEFFICIENT DEPENDENCE ON RELATIVE HUMIDITY

At any instant of time, the observed scattering coefficient depends on the amount of light scattered by the atmospheric gases and aerosols occupying the nephelometer scattering chamber. The amount of light scattered by the aerosols is determined by the physiochemical parameters which characterize the aerosols. In general, it is not possible to compute the profile of the scattering coefficient since the physiochemical parameters of the atmospheric aerosols are continuously changing and unknown. However, by certain observations to be discussed later, it is possible to obtain an insight into the variations of certain physiochemical parameters. These parameters are aerosol growth and shrinkage, and the increase and decrease of the aerosol number density. To accomplish this objective, a comparison of simultaneous scattering coefficient profiles obtained by different relative humidities is necessary.

The importance of an insight into the variations of the physiochemical parameters can be easily visualized. For instance, if the scattering coefficient is observed to increase, it might be essential to know whether the increase is due to aerosol growth, increase of aerosol number density, or a composite of aerosol growth and number density increase.

The four examples, which are discussed, were chosen to illustrate the scattering coefficient variations observed during rather diverse meteorological conditions at the RTP. For Section 3(a), the decrease of the scattering coefficient, during the passage of a low pressure system which is accompanied by rain, is of interest. For Section 3(b), there was a relatively large change of the scattering coefficient, that was observed as a cold front moved through the RTP. However, the cold front was no longer being depicted on the weather maps. Thus, it is of interest that, though the front could no longer be identified by variations of the usual meteorological parameters, the front could be identified by variations of the light scattering properties of the aerosols. The main item of interest in Section 3(c) is the occurrence of two aerosol bursts in a period of 24 hours which is unique in the observations since December 1978. For Section 3(d), the interest is on the question of whether the relative humidity has any influence on aerosols which are predominantly emissions from burning piles of wood.

3(a) Passage of Cold Front with Thunderstorms and Rain

In Figure 1, features of the scattering coefficient profiles, which should be noted, are: (1) The inside scattering coefficient is smaller than the outside scattering coefficient from 1400 until shortly before 2100 EST; (2) Shortly before 2100 EST, the inside and outside scattering coefficents decreased from about 0.15 and 0.18 km^{-1} respectively to about 0.03 km^{-1}; (3) From 2100 until 1400 EST, the scattering coefficient increased from 0.03 to 0.1 km^{-1}.

A plausible explanation for the inside scattering coefficient being smaller than the outside scattering coefficient, from 1400 until shortly before 2100 EST, is that the effective scattering size of the aerosols passing through the inside nephelometer is smaller than for the aerosols passing through the outside nephelometer. The difference in the effective scattering size can be understood as a consequence of the different relative humidities. Aerosols which pass through the inside nephelometer have experienced a relative humidity change from about 93 to 70 percent. Supposing that the aerosols have a hygroscopic component, moisture will have evaporated from the aerosols passing through the inside nephelometer. Consequently, moisture evaporation from the aerosols will result in a shrinkage of the aerosols which could account for the differences in the effective scattering size.

Before discussing the remaining features in Figure 1, the relevant meteorology needs to be considered. On May 19, a low pressure system formed in eastern Texas. Based on an examination of the RDU hourly pressure readings, the front associated with the low pressure system passed RDU

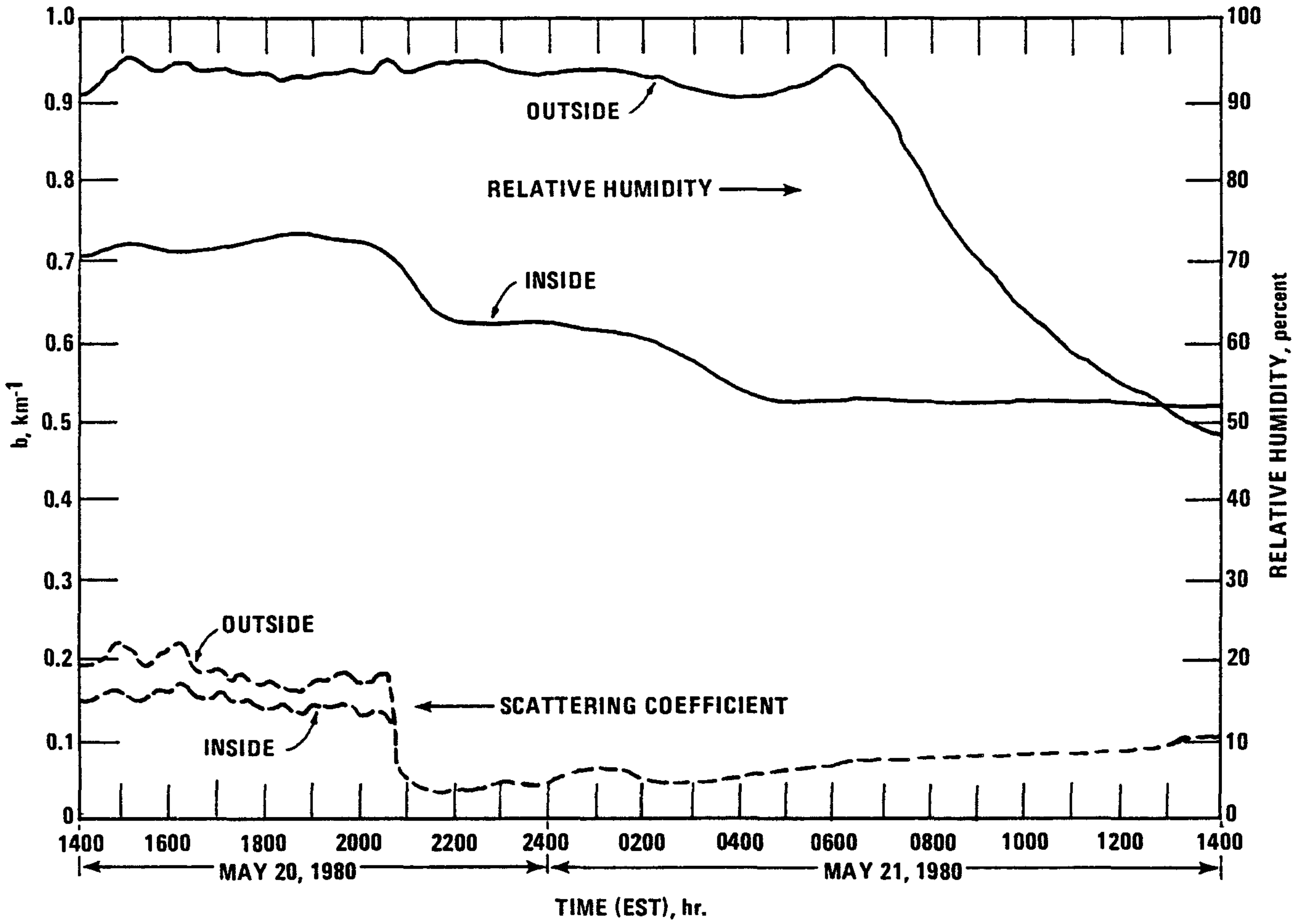

Figure 1. Profiles of the inside and outside scattering coefficient and corresponding relative humidities.

between 2100 and 2200 EST on May 20. There was extensive rainfall associated with the low pressure system. In particular, according to the RTP records, 10 mm of rain fell between 2030 and 2100 EST on May 20. Thus, it would be anticipated that aerosols could be purged by the rain.

Since the relatively rapid decrease of the inside and outside scattering coefficients occurred between 2030 and 2100 EST, the decrease can be attributed, at least partially, to a decrease of the aerosol number density which resulted from the aerosols being purged by the rain. However, it is also conceivable that the relatively larger aerosols sensed by the nephelometer are more efficiently purged than the smaller aerosols sensed by the nephelometer. If this is the case, part of the decrease of the inside and outside scattering coefficient might be due to a decrease of the effective scattering size of the aerosols. Other observations would be needed to assess the relative importance of these possibilities.

The inside and outside scattering coefficients increased from about 0.03 to 0.1 km^{-1} during the period from 2100 to 1400 EST. The most plausible explanation for the increasing trend of the inside and outside scattering coefficients is that there is an increasing trend of the aerosol number density. However, it might be possible that part of the increasing trend could be due to an increasing trend of the effective size of the aerosols. The mechanism for a possible increasing effective size is obscure. It is clear that the relative humidity would not be involved since the outside scattering coefficient did not decrease when the outside relative humidity decreased from about 95 to 50 percent between 0600 and 1400 EST. This would suggest that, after the passage of the front, the aerosols were not hygroscopic since there was no essential differences of the inside and outside scattering coefficient profiles.

3(b) Passage of Dry Cold Front

From 0200 until 2200 EST, on June 20, 1980, the nephelometer and ancillary data are depicted in Figures 2 and 3. The outside and inside scattering coefficient profiles and the corresponding relative humidity profiles are shown in Figure 2. In Figure 3, the outside scattering coefficient and relative humidity profiles, the temperature and dew point

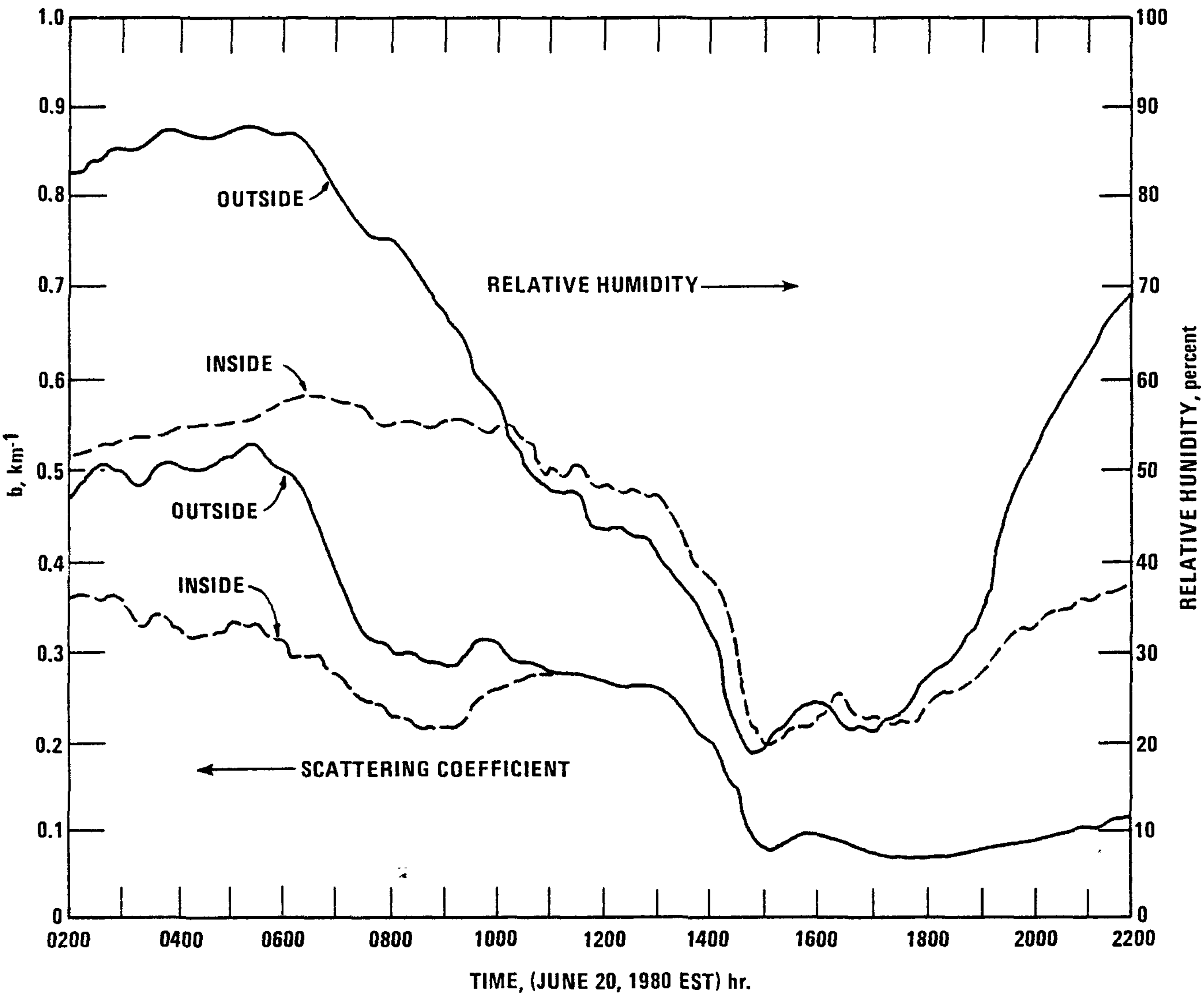

Figure 2. Profiles of the inside and outside scattering coefficient and corresponding relative humidities.

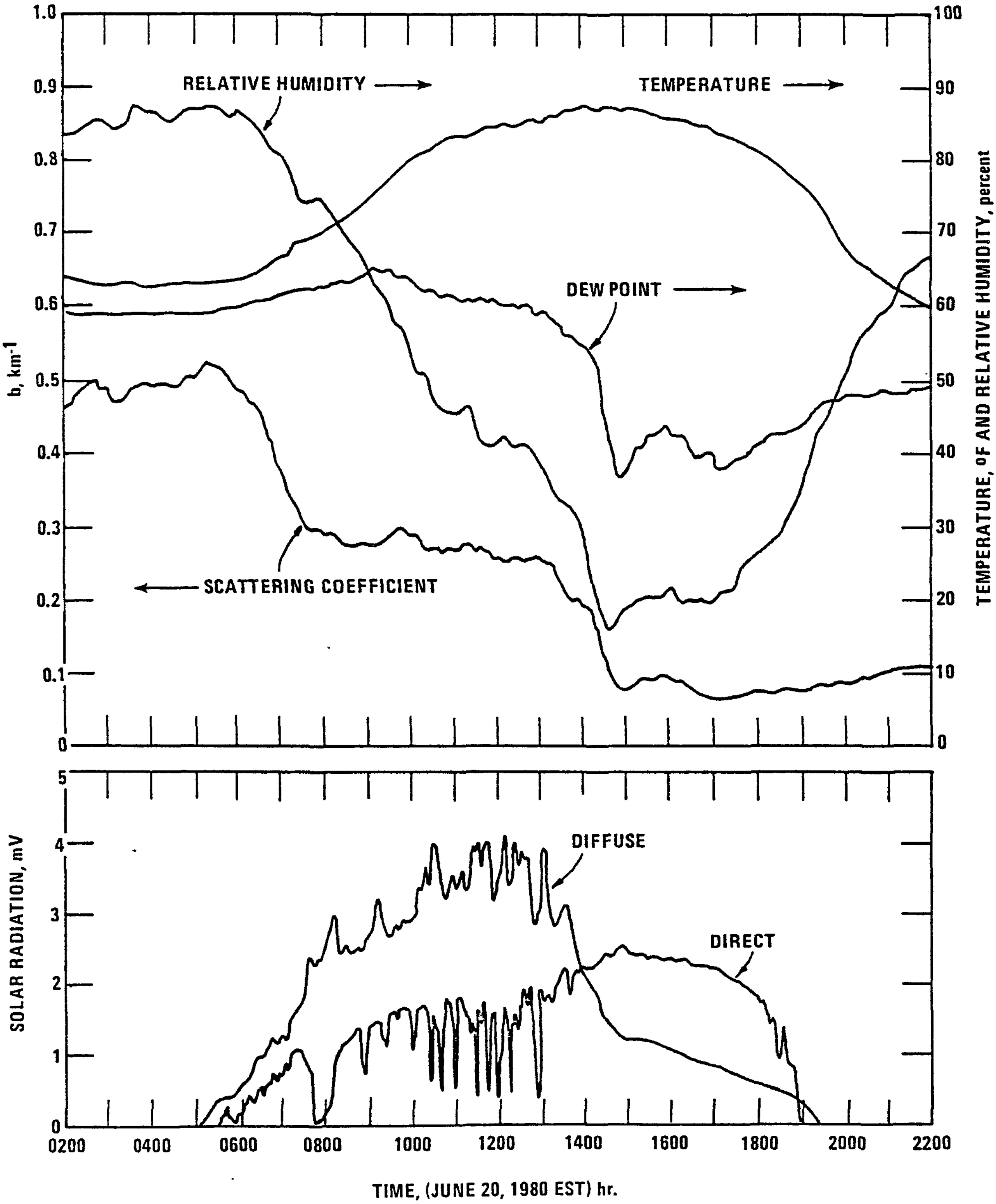

Figure 3. Profiles of the outside scattering coefficient, outside relative humidity, temperature, dew point and the diffuse and direct solar radiation flux. The diffuse and direct solar radiation flux can be expressed in Wm^{-2} by multiplying the ordinate by 3.5×10^2 and 0.97×10^2 respectively.

profiles, and profiles of the diffuse and direct solar radiation flux are shown. Before discussing the data, it will be expedient to review the relevant meteorology.

At 0700 EST on June 18, the weather map indicated that an anticyclonic weather system was centered over northern Saskatchewan, Canada. Preceeding the anticyclonic weather system was a cold front which was moving toward the RTP. At 0700 EST on June 20, the weather map indicated that the anticyclonic weather system was centered over central Illinois. However, the cold front was not shown. Presumably, the criteria specified by the weather bureau for changes of the parameters, which characterize a front, were not sufficiently satisfied to justify depicting the front on the weather map. Based on the past movement of the front, the front would have been expected to move through the RTP during the day on June 20, 1980. At the RTP, as will be seen later, there was a relatively rapid decrease of 20°F of the dew point between 1300 and 1500 EST. Undoubtedly, this indicated that there was a change of air masses which was associated with the passage of the cold front. Also, as will be seen later, there was a distinct change of the atmospheric optical properties which occurred between 1300 and 1500 EST. Perhaps, it should be noted that the RDU hourly observations did not indicate the passage of a cold front on June 20.

It will be convenient to consider various time period in Figure 2 in our discussion. From 0200 until 0530 EST, the outside scattering coefficient was observed to be larger than the inside scattering coefficient. Since the inside relative humidity is smaller than the outside relative humidity, the difference in the scattering coefficients is most likely due to the shrinkage of the aerosols as the aerosols enter the drier environment associated with the inside nephelometer. If the profiles are examined more closely, it appears that there is an anomoly during this time period which will now be discussed.

From 0200 until 0530 EST, the inside and outside relative humidity increased from 51 to 56 percent and from 82 to 88 percent respectively. Consequently, it would be expected that the inside and outside scattering coefficients would increase. However, this expectation was not observed.

Rather, it was observed that the outside scattering coefficient increased while the inside scattering coefficient decreased. To account for the decreasing trends of the inside scattering coefficient despite an increase of the relative humidity, it is plausible that there was a decreasing trend of the aerosol number density. If there was a decreasing trend of the aerosol number density, the increasing trend of outside scattering coefficient would be explained if an increase to the outside scattering coefficient, produced by the growth of the aerosols, more than compensated a decrease produced by a decrease of the aerosol number density.

Between 0530 and 0900 EST, the inside scattering coefficient decreased while the inside relative humidity was roughly constant. This indicates that the aerosol number density decreased during this period. During this period, the outside scattering coefficient decreased at a faster rate than the inside scattering coefficient. Although part of the decrease of the outside scattering coefficient can be attributed to a decrease of the aerosol number density, another mechanism is needed to account for the more rapid rate of decrease of the outside scattering coefficient. During this time period, it will be noted that the outside relative humidity was decreasing relatively rapidly which would result in a shrinkage of the aerosols. Consequently, it is very plausible that the more rapid rate of decrease of the outside scattering coefficient is due to a shrinkage of the aerosols.

From 0900 to 1300 EST, the inside and outside relative humidity decreased. There was no definite trend of the inside and outside scattering coefficients. After about 1100 EST, there were no significant differences between the inside and outside scattering coefficients. Following this rather quiescent period, there was a period of about 2 hours during which a replacement of air masses having aerosols with distinctly different optical characteristics occurred.

Between 1300 and 1500 EST, the inside and scattering coefficients decreased from about 0.27 to 0.07 km^{-1}. Although there was a decrease of about 20 percent of the inside and outside relative humidity during this period, it is not likely that shrinkage of the aerosols, due to the decrease of the relative humidity, would be of importance as an explanation for the relatively large decrease of the scattering coefficients. The reason being is that not much change in the effective size of the aerosols would be expected when the relative humidity changes from about 45 to 20 percent. It is much more plausible that a decrease of the aerosol number density was responsible, at least in part, for the relatively large decrease of the scattering coefficient. However, it is also possible that the decrease of the scattering coefficient is due, at least in part, to the ambient aerosols having a smaller effective size than the previous ambient aerosols. This might happen if there had been a major change in the source of the aerosols. The relative importance of the two explanations for the decrease of the scattering coefficient cannot be determined by our observations.

Referring to Figure 3, it will be noted that the dew point decreased by about 10°C between 1300 and 1500 EST. During this same period the outside temperature was approximately constant. Although there was no significant changes of the wind direction or speed, the rapid decrease of the dew point undoubtedly indicated the passage of the cold front mentioned earlier. Clearly, there was an influx of drier air during this period. An influx of drier air is also indicated by the profiles of the direct and diffuse solar radiation flux shown in Figure 3. Prior to 1300 EST, clouds produced the jagged appearance of the solar radiation flux profiles. After 1500 EST, the profiles are relatively smooth which indicates there were no clouds. The RDU hourly observations reported a 0.3 sky coverage of cumulus clouds at 1353 EST and no clouds after 1450 EST which are in harmony with the solar radiation observations.

Between 1300 and 1500 EST, the diffuse solar radiation flux decreased and the direct solar radiation flux increased. These changes would be expected if the aerosol number density decreased and/or the effective size of the aerosols decreased as discussed earlier. It should be noted that, although the scattering coefficient, the direct solar radiation flux and the diffuse solar radiation flux measure different aspects of light scattering by aerosols, each of the observations is in remarkable agreement with respect to the transitional period for a change in the optical properties of the aerosols.

Referring once more to Figure 2, no significant differences between the inside and outside scattering coefficients were observed between 1500 and 2200 EST. There appears to be a relatively small increase of the scattering coefficient. It is not likely that this increase is due to the increasing trend of the relative humidity. Rather, the increase is more likely due to an increasing trend of the aerosol number density and/or an increasing trend of the effective size of the aerosols.

3(c) Nocturnal Aerosol Burst

During the time span of Figure 4, an anticyclonic weather system dominated the meteorology at the RTP. Shown in Figure 4 are the profiles of the inside and outside scattering coefficient and the corresponding relative humidities.

As can be seen, the shape of the profiles for the inside and outside scattering coefficient are quite dissimilar. The inside scattering coefficient increased almost monitonically between 1400 to 0700 EST from 0.1 km^{-1} to about 0.15 km^{-1}. From 0700 to 1400 EST the inside scattering coefficient decreased relatively smoothly from about 0.15 to 0.1 km^{-1}. Obviously, the outside scattering coefficient varied in a more complex manner from 1800 to 1000 EST than the inside scattering coefficient. While the variations of the inside scattering coefficient are apparently due to an increase and decrease of the aerosol number density, the primary variations of the outside scattering coefficient are due to aerosol growth and shrinkage associated with an increase and decrease of the relative humidity. The variations of the outside scattering coefficient depicted in Figure 4 will now be discussed.

Between 1800 and 1900 EST, the outside scattering coefficient increased so that it was larger than the inside scattering coefficient. During this period, the relative humidity increased from about 45 to 60 percent. Apparently, the increase of the outside scattering coefficient is primarily due to aerosol growth. These relative humidity values are smaller than the

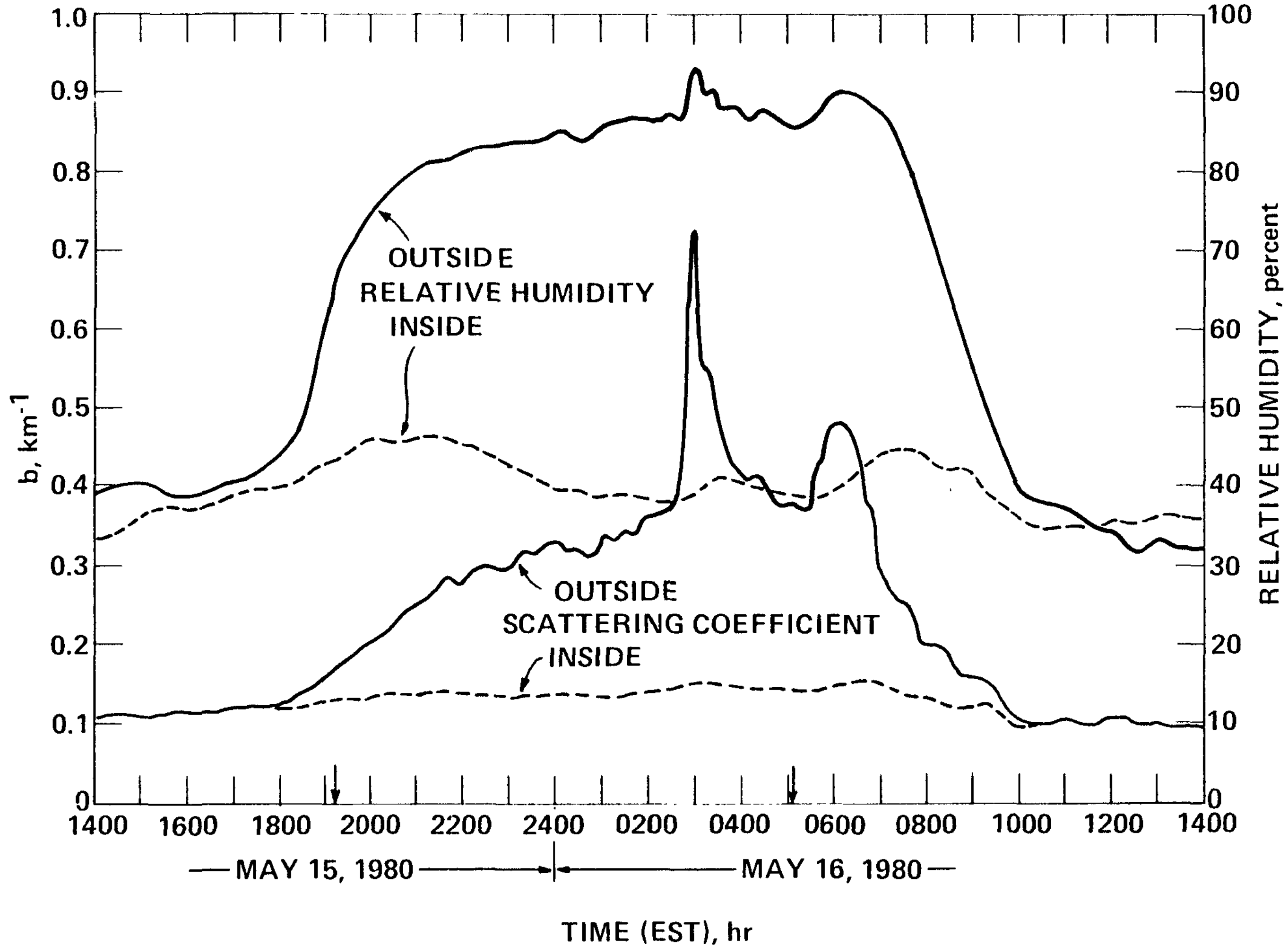

Figure 4. Profiles of the inside and outside scattering coefficient and corresponding relative humidities.

70 percent value which is usually quoted as the approximate lower bound of the relative humidity that promotes aerosol growth[6]. Although our observations indicate that the relative humidity lower bound for aerosol growth can range from about 30 percent to well over 90 percent, aerosol growth is usually observed to begin at about 50 percent at the RTP.

Primarily, as a reult of aerosol growth resulting from an increasing trend of the relative humidity, the outside scattering coefficient increased from sundown until shortly before 0245 EST. Between about 0245 and 0500 EST, a nocturnal aerosol burst occurred in response to a relatively rapid increase and subsequent decrease of the relative humidity. After sunup, another aerosol burst occurred. Primarily, the aerosol burst occurred in response to the variations of the relative humidity. As mentioned earlier, this example is unique in that two aerosol bursts occurred in a 24-hour period.

In Figure 4, the aerosol burst occurring after sunup is a composite of contributions from aerosol growth and shrinkage and an increase and decrease of the aerosol number density. However, the predominate contribution to the aerosol burst is from aerosol growth and shrinkage. This contribution can be deduced by examining the behavior of the inside and outside scattering coefficient during the aerosol burst. Since there is no essential difference in this aerosol burst and aerosol bursts which have previously been discussed[5], no further discussion on the aerosol burst after sunup will be presented.

Before discussing the nocturnal aerosol burst, it is of interest to note that the inside and outside scattering coefficient was about 0.1 km^{-1} on 1400 EST, May 15, 1980 and approximately the same 24 hours later. Thus, there was no net change of the aerosol number density during the 24-hour period shown in Figure 4.

If an aerosol burst occurs at the RTP, it usually occurs shortly after sunup. To the present time, the only other time that an aerosol burst has been observed is during the night. On three different occasions, nocturnal aerosol bursts have been observed which were associated with the passage of warm fronts. However, it is worth emphasizing that the weather maps do not indicate that a warm front could have possibly passed through the RTP during the time span shown in Figure 4. However, there was an influx of warmer air with more moisture which began arriving at about 0245 EST. This warm, moist air produced changes of the outside relative humidity that resulted in the nocturnal aerosol burst through aerosol growth and shrinkage. Probably, the warm, moist air was associated with scattered patches of ground fog which was reported in the RDU weather observations beginning at 0052 EST. Although the occurrence of the nocturnal aerosol burst can be understood in terms of relative humidity variations, it is of interest to consider some ancillary meteorological data during the period of the nocturnal aerosol burst. These data are shown in Figure 5 in which profiles of the outside scattering coefficient, wind speed, the temperature differential between 1 and 6 m above ground level, and an acoustic facsimile recording are presented between 0200 to 0325 EST.

From sundown until 0245 EST, the acoustic facsimile recording indicated that the top of the nocturnal temperature inversion was about 100 m. During this period, the temperature increased about 1°C from 1 to 6 m. In addition, the wind was calm (<2 m s^{-1}). These meteorological parameters indicated that the atmosphere was stable.

Between 0245 and 0300 EST, a spike appeared on the acoustic facsimile recording. The apex of the spike extended to at least 350 m. In appearance, the spike is quite similar to thermal plumes which are observed during the day. In any case, there was a transition from a laminar to a turbulent atmospheric boundary layer. After 0300 EST, the top of the atmospheric boundary layer was undulating in height from about 100 to 180 m.

The increase in wind speed also suggests atmospheric mixing. Shortly after 0230 EST, the wind speed was about 1 m s^{-1}. Shortly after 0245 EST, the wind fluctuated with an average of about 2 m s^{-1}. For the remainder of the night, the wind speed averaged about 2 m s^{-1}.

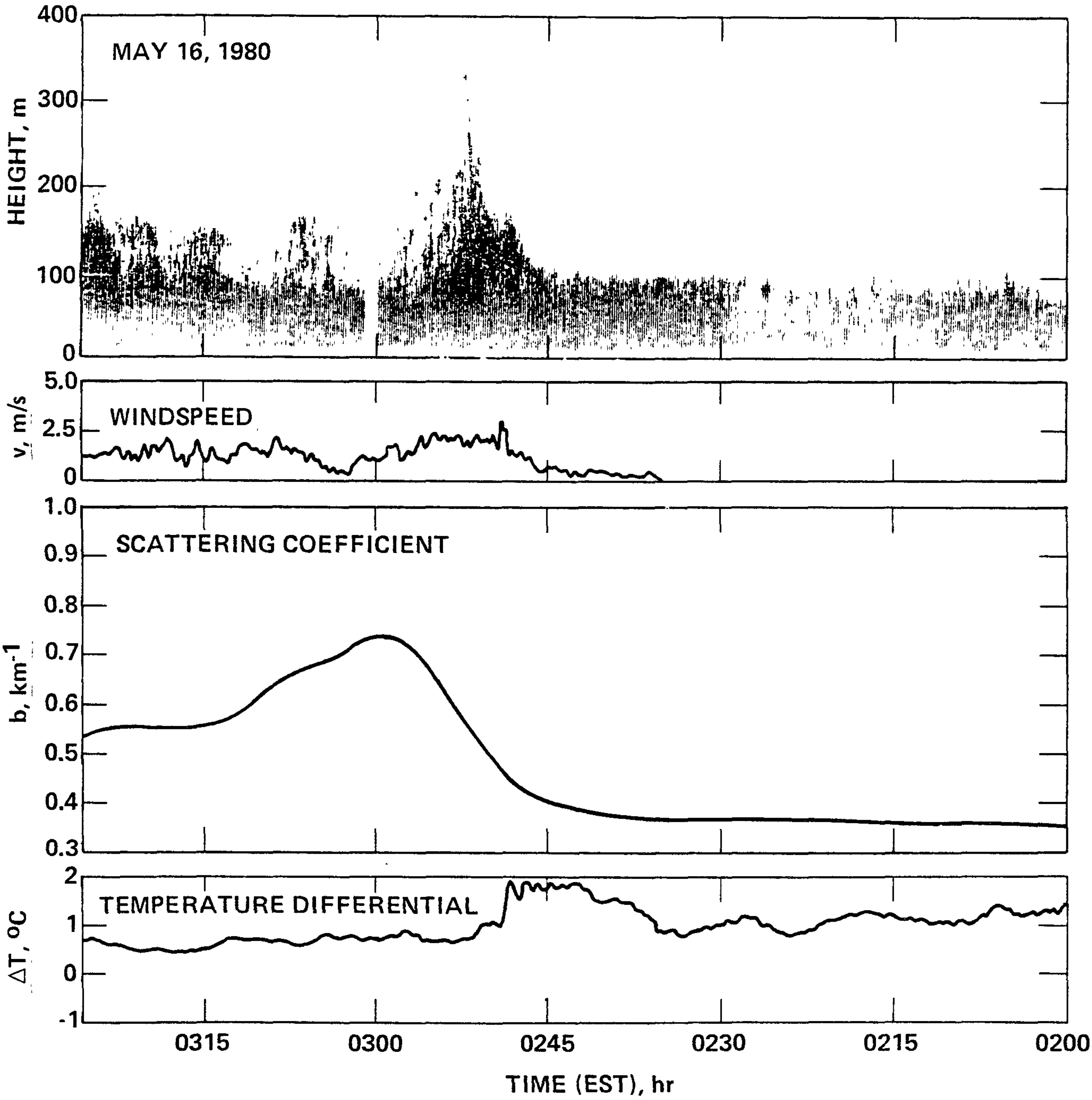

Figure 5. Profiles of the outside scattering coefficient, wind speed, the difference in temperature at 6 and 1 m, and an acoustic facsimile recording. A positive temperature difference indicates that the temperature is warmer at 6 m than 1 m. Time increases from right to left.

As will be noted, the difference in temperature between 1 and 6 m increased from 1°C to 2°C from 0230 to 0245 EST. Shortly after 0245 EST, the difference in temperature decreased to about 0.8°C and was roughly the same until sunup.

While there was an atmospheric disturbance due to some unknown source which appeared at about 0245 EST, it is by no means clear what relation the atmospheric disturbance had to the influx of warmer air with more moisture. Evidently, the meteorological conditions were somewhat unique since it might be anticipated that nocturnal aerosol bursts would be observed much more often.

3(d) Drifting Wood Smoke

Occasionally, the largest contribution to the scattering coefficient is due to emissions drifting to the RTP observational site from burning tree piles. The tree piles are a by-product of site preparation for building construction or some other purpose. Usually, the presence of wood smoke aerosols are detected during the night when the atmosphere is stable. In addition to the distinctive jagged appearance of the scattering coefficient profile, the presence of wood smoke aerosols can be confirmed by smell if the concentration is sufficient. As a consequence of the burning tree piles, it is possible to examine the question of whether wood smoke aerosols are affected by the relative humidity.

In Figure 6, profiles of the inside and outside scattering coefficient and corresponding relative humidities are shown for a case in which the scattering of light from wood smoke aerosols is the major contributor to the scattering coefficient during the night. The jagged appearance of the scattering coefficient profiles is typical for wood smoke aerosols. The burning tree piles for this example were located about 3 km to the east of the RTP observational site.

A profile of the wind speed is also shown in Figure 6. As can be seen, the wind was fairly calm during the night. The observations indicated that the wind direction was easterly. If it is assumed that the wind speed was

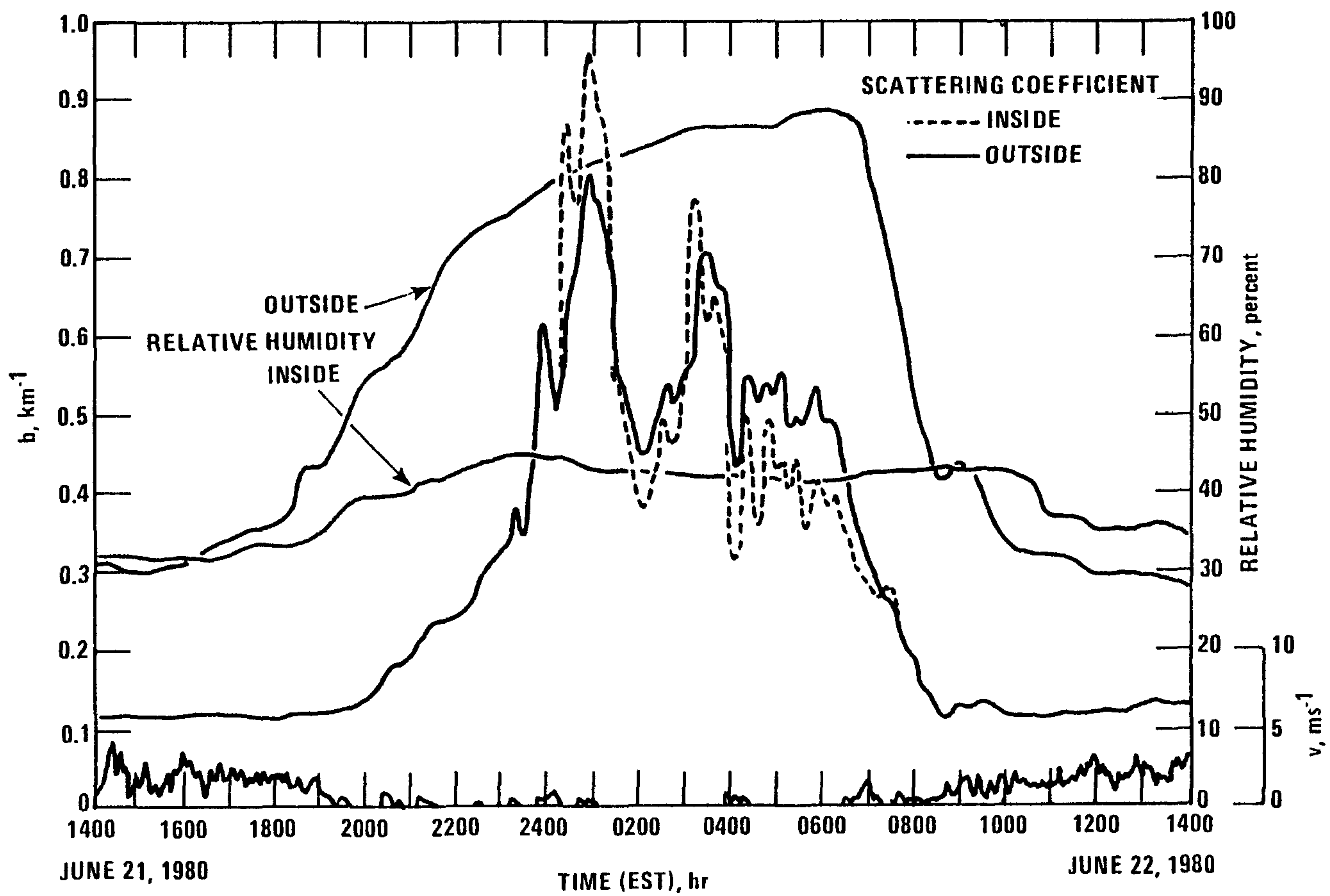

Figure 6. Profiles of the inside and outside scattering coefficient and corresponding relative humidities.

1 m s^{-1}, the lower bound on the travel time of the wood smoke aerosols to the RTP observational site would be about 1 hour. Presumably, 1 hour would be sufficient for the wood smoke aerosols to be in equilibrium with respect to absorption of atmospheric moisture.

Examining Figure 6, it will be noted that the outside relative humidity was larger than the inside relative humidity during the night. Thus, it would be expected that the outside scattering coefficient would be larger than the inside scattering coefficient during the night. No differences between the inside and outside scattering coefficients were observed until after 2400 EST. On the other hand, the inside scattering coefficient was larger than the outside scattering coefficient shortly after 2400 EST for a period of about 1 hour. Obviously, neither of these observations conform to the expectations.

Probably the wood smoke aerosols started arriving at the RTP observational site at about 2000 EST. If this were the case, then from 2000 and shortly before 2400 EST the wood smoke aerosol number density was mixed well enough so that any fluctuations of the emissions from the burning tree piles were not observed. Since the inside and outside scattering coefficients were the same, this observation might suggest that the relative humidity does not influence the growth and shrinkage of the aerosols.

From 2400 to 0700 EST, the profiles of the inside and outside scattering coefficients were quite jagged. In addition, the differences in magnitude of the profiles are somewhat random. A source of the jagged appearance of the profiles would result from the temporal fluctuations of the emissions from the burning tree piles. The differences in the magnitude of the profile can best be understood as being due to the inlet orifices to the inside and outside nephelometers being 50 m apart. If the wood smoke aerosols were not mixed sufficiently in the journey to the RTP, differences in the inside and outside scattering coefficients would be expected, provided spatial inhomogeneities of the wood smoke aerosols were less than 50 m.

In summary, as evidenced by the scattering coefficient observations from 2000 to 2400 EST, wood smoke aerosols do not appear to be affected by the relative humidity. After 2400 EST, fluctuation phenomena obscure any possible deductions concerning the influence of relative humidity on wood smoke aerosols. Analysis of observations on other occasions suggest similar conclusions.

SECTION 4

VISIBILITY VARIATIONS

In other studies[7], it was found that the RDU visibility observations are well correlated with the inverse of the scattering coefficient observed at the RTP. Exceptions to this correlation would be expected if emissions from a local source were being transported to one site but not being transported to the other site. Thus, it is of interest to examine the relationship between the RDU visibility observations and the inverse of the scattering coefficient for the examples which have been presented during the period of greatest interest.

During the period presented in Table I for Figure 1, RDU reported scattered thunderstorms, periods of light rain, and patches of fog from 1752 to 2050 EST. Due to the meteorological conditions, a comparison of the visibility and the inverse outside scattering coefficient might be anticipated to be somewhat nebulous. Despite this reservation, upon comparing the visibility data of Table I with the data presented in Figure 1, it will be noted that the expected trend of better visibility between 2100 and 2200 EST was observed. In addition, the temporal behavior of the visibility is in qualitative agreement with the outside (or inside) scattering coefficient although the agreement is by no means a one-to-one correspondence.

During the period presented in Table I for Figure 2, RDU reported haze as an obstruction to vision between 1053 and 1353 EST. During the same period, there was a broken sky coverage of cumulus clouds. After 1353 EST, no haze or clouds were reported by RDU. For this example, there is not only an excellent qualitative agreement between the visibility and the inverse of the outside scattering coefficient but there is quantitative agreement with an empirical relationship between the visibility and the inverse outside scattering coefficient derived in a previous study[7]. This agreement is

TABLE I. HOURLY VISIBILITY

Figure	Date	Time (EST)	Visibility (Miles)
1	May 20, 1980	1752	5
		1850	2
		1950	1
		2050	4
		2150	10
		2350	12
2	June 20, 1980	1053	4
		1153	4
		1257	5
		1353	5
		1450	10
		1550	10
4	May 16, 1980	0150	10
		0250	10
		0351	3
		0450	3
		0551	4
		0650	7
		0750	7
		0851	10
6	June 21-22, 1980	1850 to 0350	15

not surprising since the conditions for the relationship to be valid is fulfilled for this example.

During the period presented in Table I for Figure 4, RDU reported patchy ground fog at 0150 and 0250 EST. From 0350 to 0550 EST, RDU reported fog. A clear sky was reported by RDU from 0150 to 0851 EST. For this example, there is little qualitative agreement between the visibility and the outside scattering coefficient. For instance, by inspecting Figure 4, it would be anticipated that the visibility would have been observed to deteriorate quite rapidly between 0200 and 0300 EST. The RDU observations indicates a rapid decline of visibility between 0250 and 0351 EST. Perhaps, a more striking discrepancy with expectations can be noted by observing that the double peak of the outside scattering coefficient cannot be anticipated by use of the visibility data. Beginning at 0750 EST, there is quantitative agreement with an empirical relationship between the visibility and the inverse outside scattering coefficient mentioned previously.

During the period presented in Table I for Figure 6, the visibility was 15 miles (24 km) from 1850 to 0350 EST. Subsequently, the visibility was 10 miles (16 km). It is obvious that no relationship exists between the visibility as observed at RDU and the outside scattering coefficient as observed at the RTP. The reason is quite simple to understand. RDU is located approximately 6 km to the east. The burning tree piles were located about 3 km to the east. Thus, with a light east wind, the burning tree piles would be a local source for the RTP but not for RDU.

SECTION 5

CONCLUDING REMARKS

In general, if the aerosol size and/or the aerosol number density varies, the scattering coefficient would be expected to vary. If only the scattering coefficient is observed, it is not possible to deduce the reason for the variations of the scattering coefficient. If the scattering coefficient and the relative humidity in the scattering chamber is observed, it is still ambiguous on the relative changes of the aerosol size and number density.

The significance of the research presented in this report is that by operating two nephelometers at different relative humidities, it illustrates how information on the relative temporal contributions of aerosol growth and shrinkage and the increase and decrease of the aerosol number density to the scattering coefficient can be deduced. Many other examples could have been discussed. The examples presented in this paper were arbitrarily selected to illustrate variations under diverse meteorological conditions.

REFERENCES

1. Ahlquist, N. C. and R. J. Charlson, 1967: A New Instrument for Evaluating the Visual Quality of Air. J. Air Pollutant Control Association. 17:467-469.

2. Twomey, S., 1977: Atmospheric Aerosols, Elsevier Scientific Publishing Company, 302 pp.

3. Orr, C., F. K. Hurd, and W. J. Corbett, 1958: Aerosol Size and Relative Humidity. J. Collid Science 13:472-482.

4. Winkler, P., 1973: The Growth of Atmospheric Aerosol Particles as a Function of Relative Humidity - II. An Improved Concept of Mixed Nuclei. Aerosol Sci. 4:373-387.

5. Griffing, G. W., 1981: Dependence of Nephelometer Scattering Coefficients on Relative Humidity: Evolution of Aerosol Bursts. EPA 600/4-81-030. 38 pp.

6. Charlson, R. J., A. P. Waggoner, and J. F. Thielke, 1978: Visibility Protection for Class I Areas, the Technical Basis. Council on Environmental Quality Document (NTIS PB-288842), Washington, D.C., 1-113.

7. Griffing, G. W., 1980: Relation Between the Prevailing Visibility, Nephelometer Scattering Coefficient, and Sunphotometer Turbidity Coefficient. Atmos. Environ. 14:577-584.

TECHNICAL REPORT DATA

(Please read Instructions on the reverse before completing)

1. REPORT NO.	2.	3. RECIPIENT'S ACCESSION NO.
4. TITLE AND SUBTITLE DEPENDENCE OF NEPHELOMETER SCATTERING COEFFICIENTS ON RELATIVE HUMIDITY Fronts, Nocturnal Disturbance, and Wood Smoke		5. REPORT DATE 6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) George W. Griffing		8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS (Same as block 12)		10. PROGRAM ELEMENT NO. ADTA1D/03-1327 (FY-81) 11. CONTRACT/GRANT NO.
12. SPONSORING AGENCY NAME AND ADDRESS Environmental Sciences Research Laboratory - RTP, NC Office of Research and Development U.S. Environmental Protection Agency Research Triangle Park, NC 27711		13. TYPE OF REPORT AND PERIOD COVERED 14. SPONSORING AGENCY CODE EPA/600/09
15. SUPPLEMENTARY NOTES		

16. ABSTRACT

The dependence of the nephelometer scattering coefficient of atmospheric air on the relative humidity at the RTP is discussed for four different meteorological examples. These examples feature (1) the passage of a low pressure system with thunderstorms, (2) the passage of a cold, dry front, (3) a nocturnal weather disturbance due to an unknown source, and (4) wood smoke aerosols from burning tree piles. Nephelometer scattering coefficient data were obtained by the use of two nephelometers. One nephelometer was operated at the ambient outside relative humidity and the other nephelometer at a different relative humidity. Using this operational mode of data acquisition, qualitative temporal information was deduced on the variations of aerosol size and number density as various meteorological parameters vary. The temporal trend of the visibility is also discussed for each example.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group

18. DISTRIBUTION STATEMENT RELEASE TO PUBLIC	19. SECURITY CLASS *(This Report)* UNCLASSIFIED	21. NO. OF PAGES 36
	20. SECURITY CLASS *(This page)* UNCLASSIFIED	22. PRICE

EPA Form 2220-1 (9-73)